LAWRENCE LIVERMORE NATIONAL LABORATORY

LLNL-TR-642028

Experimental Determination of the 12 rad Line Around Bldg 332 from a Maximum Credible Criticality Accident

D. E. Hankins

August 7, 2013

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

CSM-754

Experimental Determination of the 12 rad Line Around Bldg 332 from a Maximum Credible Criticality Accident

Report Date: July 14, 1995

Dale E. Hankins

Experimental Determination of the 12 rad Line Around Bldg 332 from a Maximum Credible Criticality Accident

Dale E. Hankins

Table of Contents

Experimental Determination of the 12 rad Line Around Bldg 332 from a Maximum Credible Criticality Accident

Dale E. Hankins

Introduction

ANSI standard ANSI/ANS-8.3-1986[1] specified the areas that do not have to be included in the criticality alarm evacuation. Section 4.2.2 of this standard states, "A criticality alarm system is not required by this standard in areas where the maximum foreseeable absorbed dose in free air will not exceed 12 rad. For the purpose of this evaluation a maximum yield may be assumed not to exceed 2 x E19 fissions for events outside reactor cores". The B332 SAR[2] and the site-wide EIS/EIR (DOE, 1992d)[3] have determined that the maximum credible fission yield for an inadvertent nuclear criticality in Bldg 332 is 1 x E18 fissions. Therefore, 1 x E18 fissions is used as the maximum credible criticality yield in this report.

During the test of the criticality alarm system in Bldg 332 on March 18, 1995,[4] we also obtained data outside the building to be used to determine the location of the 12 rad line. These results have been analyzed and we have prepared a drawing showing the location of the 12 rad line around Bldg 332.

Experimental Methods

The dose rates from the Co-60 source were measured outside Bldg 332 at various preselected distances and angles. To mock-up the worst case scenario for an accident occurring in Bldg 332, we placed the Co-60 source near the exit doorways to rooms 1321, 1329, and 1378. An accident occurring elsewhere in a room in Bldg 332 would deliver less dose to personnel outside the building because of the greater distance to the excursion and the absorption of the radiation in the 8 inch thick concrete walls and equipment in the building.

The rooms selected for the Co-60 source exposures and the location of the measurement points were chosen to provide the following information. Data obtained with the source in the doorway of room 1321 was used to determine if the 12 rad line extended into Bldg 331 and if so, how far it extended into the building. The data obtained with the source in the doorway of room 1329 was used to determine if the assembly area located between Bldgs 331 and 332 is outside the 12 rad line and also if the "Beta room" inside Bldg 331 can be used as an assembly or emergency management area. The data obtained with the source in the doorway of room 1378 was used to determine how far the 12 rad line extended from Bldg 332, and to compare the measured readings with the calculated dose rates at these distances.

To determine the location of the 12 rad line north of Bldg 332, survey instrument readings were made directly north of the building with the Co-60 source exposed in the NE corner of room 1378. These measurements were made through the 8 inch thick concrete wall of Bldg 332, at the outer fence to the superblock area.

Victoreen 450 survey instruments, that had been calibrated recently in the Bldg 255 calibration facility, were used to make the dose rate measurements. To limit personnel exposure, the measurements made in the higher dose rate areas were made with the instruments placed on stands or supports at about chest height above the ground. These instruments were operated in the integrate mode. Measurements made in the lower dose rate areas were made with hand held instruments operating in the dose rate mode.

Discussion of Evaluation Methods

The rad dose delivered during an accident with a yield of 1 x E18 fissions is not a constant value and will depend on the type of critical system involved, i.e. solution, metal, metal reflected, or reactor. These variations in the rad dose per fission will change the distances to the 12 rad line for the different systems. The distance to the 12 rad line will be less for the lower dose systems than for the higher dose systems.

Examples of the dose delivered during an excursions are given in the ANSI standard for several types of critical assemblies. The largest dose per fission is delivered by the Godiva unreflected U-235 metal assembly. The standard indicates that the Godiva assembly produces 750 rad at a distance of 2 m from the assembly from a burst of 5 x E16 fissions. Extrapolating up to the maximum specified accident of 1 x E18 fissions, the dose is 6.0 x E4 rad at a distance of 1 m. However, a burst of this size by a metal system is not possible because the metal would melt and burn long before a yield this large could be produced. For example, the criticality accident that occurred at LLNL in 1963 produced 3.76 x E17 fissions and caused the uranium core to disassemble and the uranium to catch fire and partially burn. This accident produced the largest number of fissions of any recorded accident of a metal system. The second largest accident was a burst of 1.2 x E17 from an excursion in 1957 of the Godiva assembly at LASL. The uranium core is reported to have oxidized and was close to melting, and the support mechanism for the core was badly bent. The ANSI standard also states that accidents involving compact spheres are not considered very likely today.

The most likely excursion that could occur in Bldg 332 and approach 1 x E18 fissions would have to be from a solution accident. The SAR for Bldg 332 indicates that the maximum possible fission yield in an accident would be from a powder/liquid slurry system or an aqueous system, both with yields of 5 x E 17 fissions (we use 1 x E18 fissions for the calculations made below). To get this large a yield, the accident would consist of multiple pulses and remain in a critical state for a long period of time. An accident of the pulsing type occurred in 1958 at the Y-12 facility at Oak Ridge, TN. This accident was a highly enriched uranium solution in a 55 gallon drum that continued to pulse over a 42 minute period, and produced an estimated 1.3 x E18 fissions. This is the largest known accident that has occurred in a nonreactor-type system. This excursion was terminated when water continued to be added to the drum and the solution became too dilute to maintain a critical state.

The dose from solution systems is less per fission than from metal systems. The ANSI standard indicates that the CRAC solution critical assembly has a dose rate of 0.8 rad/s at 2 m from 1.3 x E14 fissions/s. For the maximum accident of 1 x E18 fissions the dose delivered at 1 meter would be 2.46 x E4 rad. This is very close to the dose given in the standard for 2 fatal process accidents involving solutions (LASL, 1958, 1.5 x E17 fissions and Wood River Junction, 1964, 1.3 x E17 fissions). The estimated dose is 2.5 x E4 rad at 1 m for an accident of 1 x E18 fissions. The results from an experimental model of the Y-12 accident indicate it would have produced 3.65 x E4 rad from the maximum 1 x E18 fission accident.

Three other doses from critical assemblies are given in the standard and can be scaled to the maximum accident of 1 x E18 fissions. The Parka Assembly (a 35 in. diameter graphite moderated reactor system) would deliver a dose of 1.2 x E4 rad at 1 m from the maximum accident. Two accidents involving partially reflected Pu-239 (LASL, 1945, 1 x E16 fissions, and LASL, 1946, 3 x E15 fissions) would have delivered about 4.35 x E4 rad at 1 m from the maximum accident.

We need not consider the results from the Parka Assembly because it is a reactor system and is therefore excluded by the ANSI standard. The two partially reflected Pu-239 accidents can be excluded because they could never reach 1 x E18 fissions. The remaining systems which must be considered are the CRAC assembly at 2.46 x E4 rad, the two solution accidents at 2.5 x E4 rad and the Y-12 mock-up at 3.65 x E4 rad. Because of the uncertainties in the dose determinations, the difference between these doses is not significant. As three of the four systems would have produced a dose of 2.5 x E4 rad from the maximum accident, we elected to use this value in this report to determine the distance to the 12 rad line for Bldg 332. The distance to a 12 rad line using the dose value from the Y-12 mock-up assembly would be only slightly greater and would not change the conclusions made in this report.

Experimental Results

The location of the measurement points and the readings obtained with the survey instruments during the study are shown in Figures 1 through 5. The instrument readings shown in Figure 1 were made to determine if the assembly area was outside the 12 rad line and if the Beta room in Bldg 331 could be used as an assembly area or emergency management area. Figure 2 shows the instrument readings obtained to determine if Bldg 331 is inside the 12 rad line. Figure 3 shows the instrument readings obtained to determine the distance to the 12 rad line.

Figures 3, 4 and 5 show the instrument readings made by the Health and Safety technician as he moved along the outside fence of the superblock area making measurements at each fence post (10 foot spacing). Figure 3 shows the instrument reading he obtained during test #45 with the source located in the doorway to room 1378. The dose rates increased as the Health and Safety technician moved to the East along the fence, peaking at 28 mR/h at 100 feet East of the building, and decreasing to 10 mR/h at 180 feet. The instrument readings obtained for tests #41 and #42 are shown in Figures 4 and 5. Test #41 was made with the Co-60 source located in the SE corner of room 1378 and test #42 was made with the Co-60 source located in the NE corner of room 1378.

The location of the 12 rad line at the North end of the building was determined by using the instrument readings of 18 mR/h with the Co-60 source located at the NE corner of room 1378.

The readings of the survey instruments have been plotted in Figure 6. A curve has been drawn using the data points, except for the measurements made at 45 degrees from room 1378 and at the assembly area (shielding by concrete walls decreased these readings). The regression curve shown is a non-linear least squares determination to a power function.

Also shown in Figure 6 is a curve showing the calculated dose rate as a function of the distance from the building. These calculations were made using the inverse square relationship and an additional air absorption factor of 1/3 as suggested in appendix B of the ANSI standard.[1] The measured data drops more rapidly than the calculated values.

Discussion of the Results

To determine the distance to the 12 rad line, we used the curve in Figure 6 that was derived from the measured dose rates. Because of the uncertainties in the air absorption factors for air (probably too large at these short distances), we consider the measured curve to be more accurate than the calculated curve. The distance to the 12 rad line would have been less if the calculated curve had been used.

The instrument reading at an angle of 45 degrees with the source located in the doorway to room 1378, is significantly below the curve measured at 0 degrees (directly opposite doorway) and was used to determine the distance to the 12 rad line at this angle. The instrument readings made at the assembly area between Bldg 331 and 332, are also much lower than predicted using the measured 0 degree curve, which is caused by the attenuation of the radiation by the walls of room 1309.

Also shown in Figure 6 are the dose rates from the Co-60 source that correspond to the 12 rad line for a 1 x E18 fission accident for each of the critical assemblies or accidents given in the ANSI standard (except for the Parka assembly). These dose rates and distances to the 12 rad line were found by comparing the dose at 1 meter from the assembly, or accidents, to the dose at 1 m from the Co-60 source. For example, the dose from the CRAC critical assembly is 2.46 x E4 rad for the maximum excursion of 1 x E18 fissions and the dose rate from the Co-60 source is 143 R/h. Assuming the CRAC assembly would operate for 1 h to produce this dose, the ratio of doses is 2.46 x E4/143 = 172. The dose rate from the Co-60 source that would correspond to 12 rad is then, 12 rad/h divided by 172 = 69.7 mR/h. The distance corresponding to 69.7 mR/h is calculated using the regression equation at the bottom of Figure 6 (or found using the "measured" line) to be at 34.0 m.

Conclusions

Figure 6, shows the 12 rad lines for Bldg 332 using the dose values given for the CRAC solution critical assembly and the 2 fatal solution accidents. A solution accident is the only accident scenario for Bldg 332 that could produce 1 x E18 fissions. This 12 rad line lies within the superblock area and does not extend into Bldg 331. It does however, include the fenced area on the East side of Bldg 331. The present assembly area is outside the 12 rad line and the "Beta" room can be used as an assembly or emergency management area.

The 12 rad lines shown in Figure 6 is not a composite of circles. The shorter distance to the 12 rad line North of the building is caused by the shielding provided by the 8 inch thick concrete walls of the Pu building. The curvature in the 12 rad line at the SW corner of the building is from shielding provided by the walls of room 1309. We did not attempt to evaluate the 12 rad line inside Bldg 332 because the entire building is included in the criticality alarm coverage.

References

1. Criticality Accident Alarm System, American National Standard, American Nuclear Society, ANSI/ANS-8.3-1986.

2. Safety Analysis Report, Defense and Nuclear Technologies Directorate, LLNL, UCRL-AR-119434, Vol 1, Rev. 0.

3. DOE (1992d), Final Environmental Impact Statement and Environmental Report for the Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore, U.S. Department of Energy, Washington, DC, DOE/EIS-0517, SCH90030847, August 1992

4. Dale E. Hankins, Additional Study of the Response of the Criticality Alarm Systems in Bldg 332 to Co-60 Gamma-Rays, Criticality Safely Memo CSM-721, March 1, 1995

Figure 1. Schematic showing the measurement locations and the survey instrument readings obtained with the source located at the exit door to room 1321.

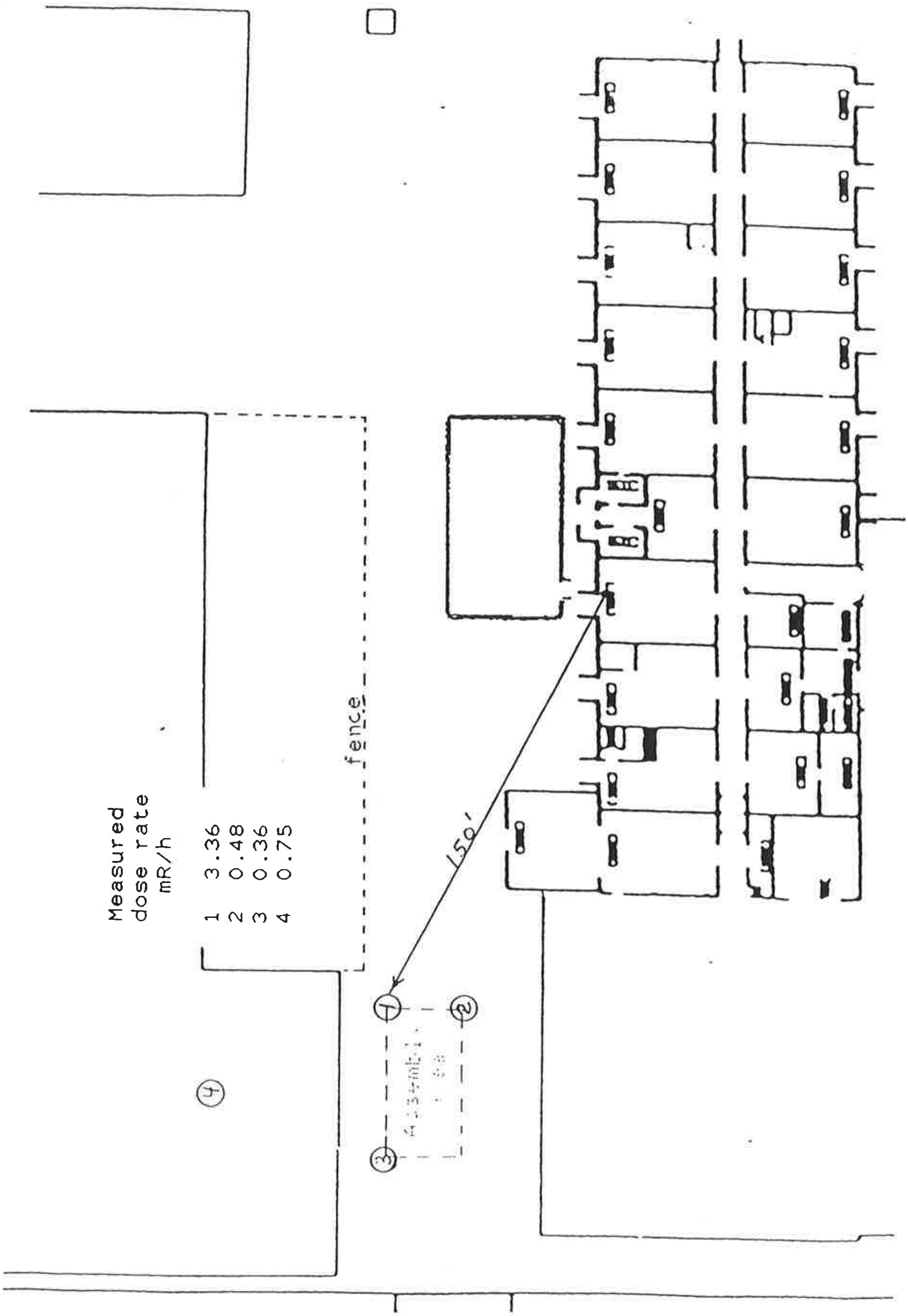


Figure 2. Schematic showing the measurement locations and the survey instrument readings obtained with the source located at the exit door to room 1329.

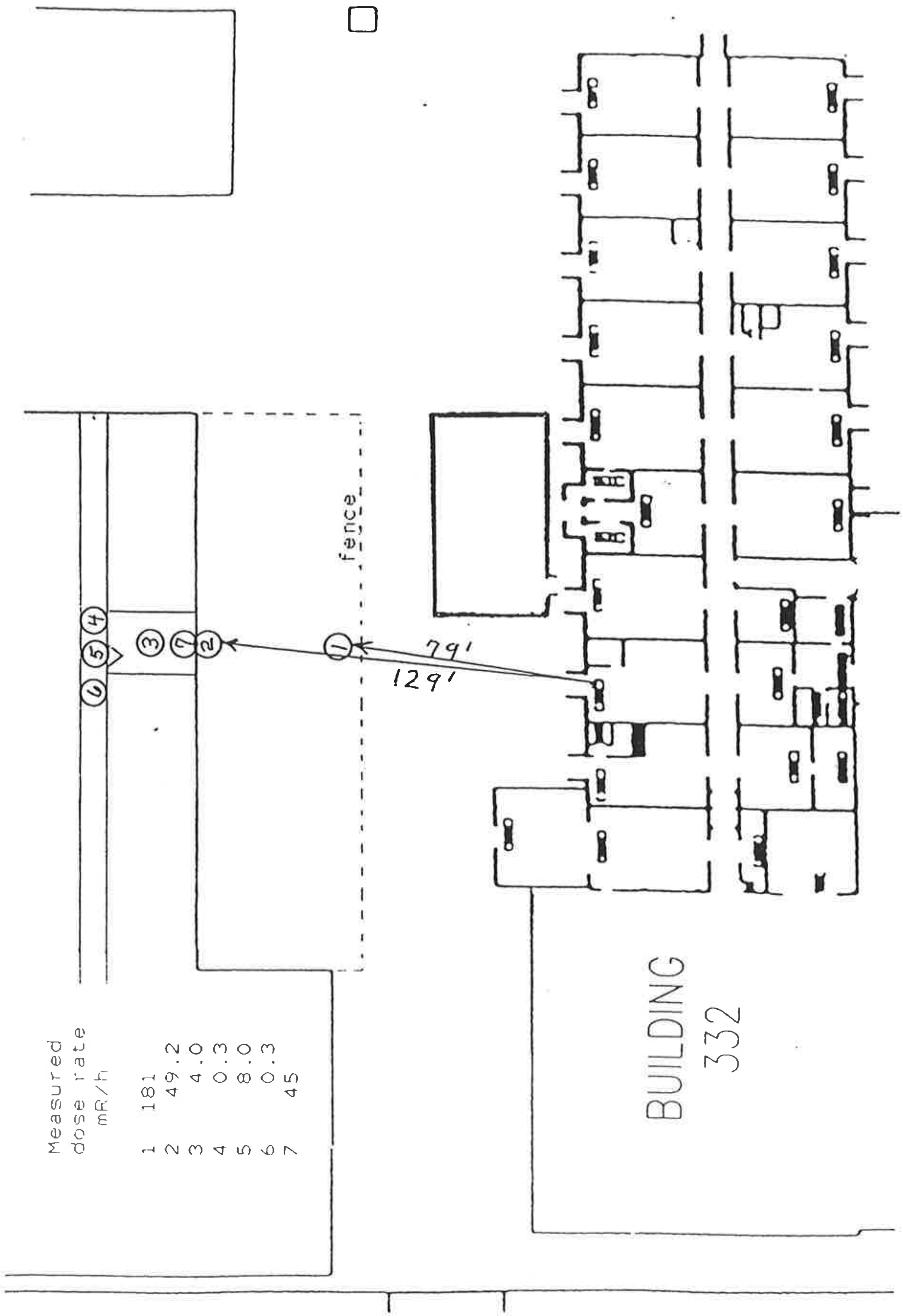


Figure 3. Schematic showing the measurement location and the survey instrument reading obtained outside Bldg 332 with the source located at the exit door to room 1378. Also shown are the instrument readings obtained at 10 foot intervals along the outside fence line to the North of Bldg 332.

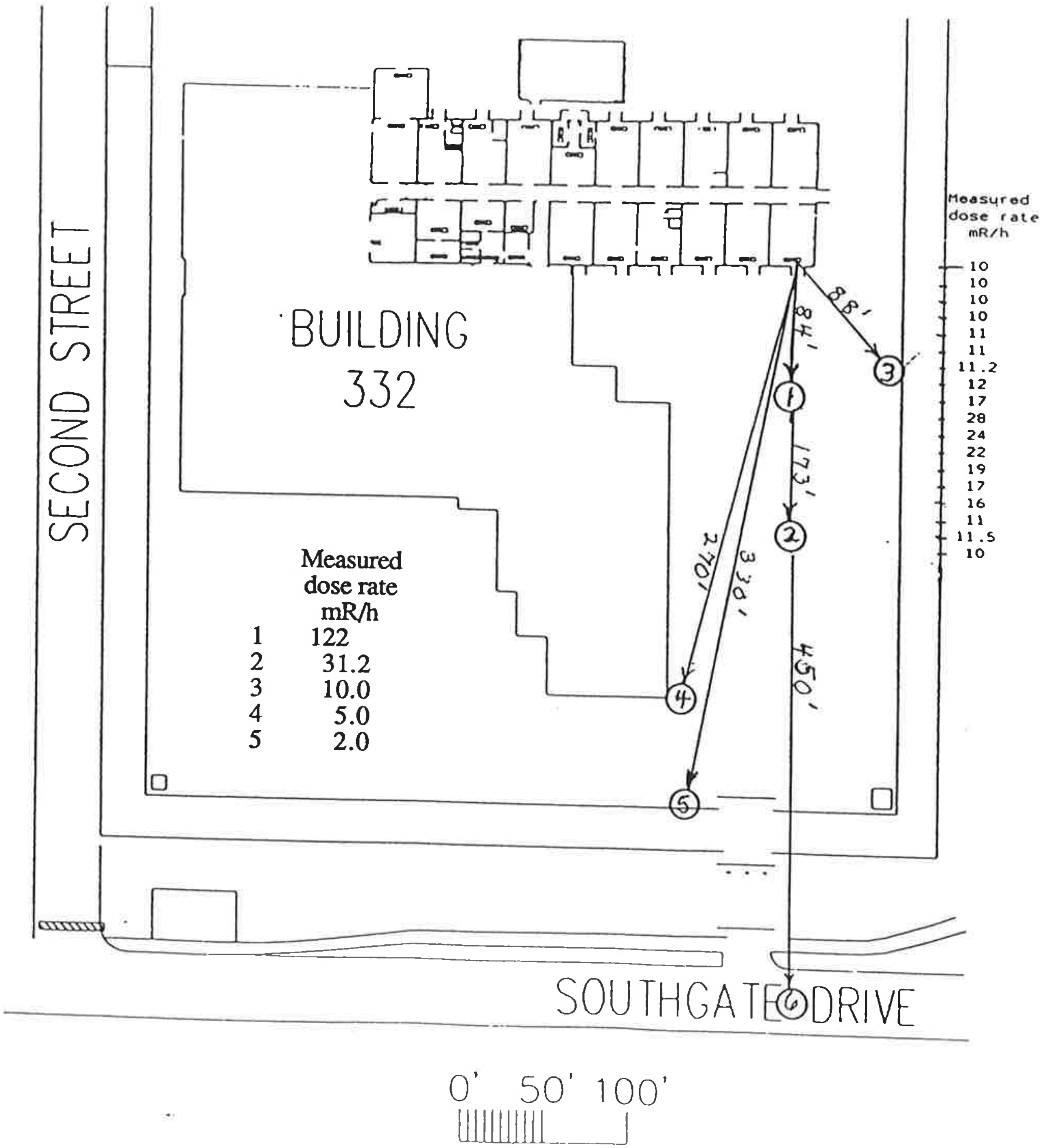


Figure 4. Schematic showing the survey instrument readings recorded by the Health and Safety Technician next to the outer superblock fence North of Bldg 332. The Co-60 source was located in the SE corner of room 1378. Each of the dose rates were obtained at 10 foot intervals along the fence.

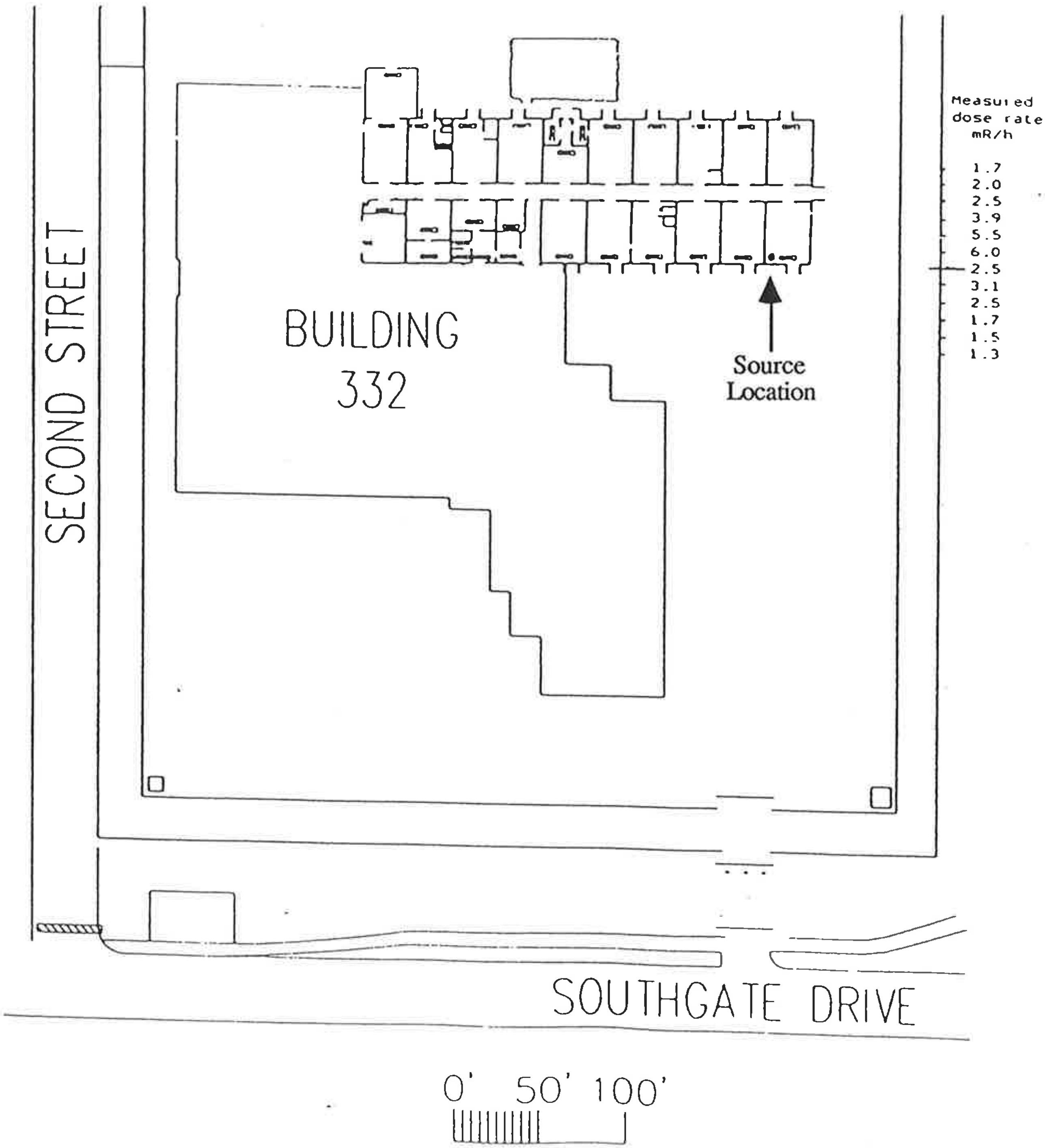


Figure 5. Schematic showing the survey instrument readings recorded by the Health and Safety Technician next to the outer superblock fence North of Bldg 332. The Co-60 source was located in the NE corner of room 1378. Each of the dose rates were obtained at 10 foot intervals along the fence.

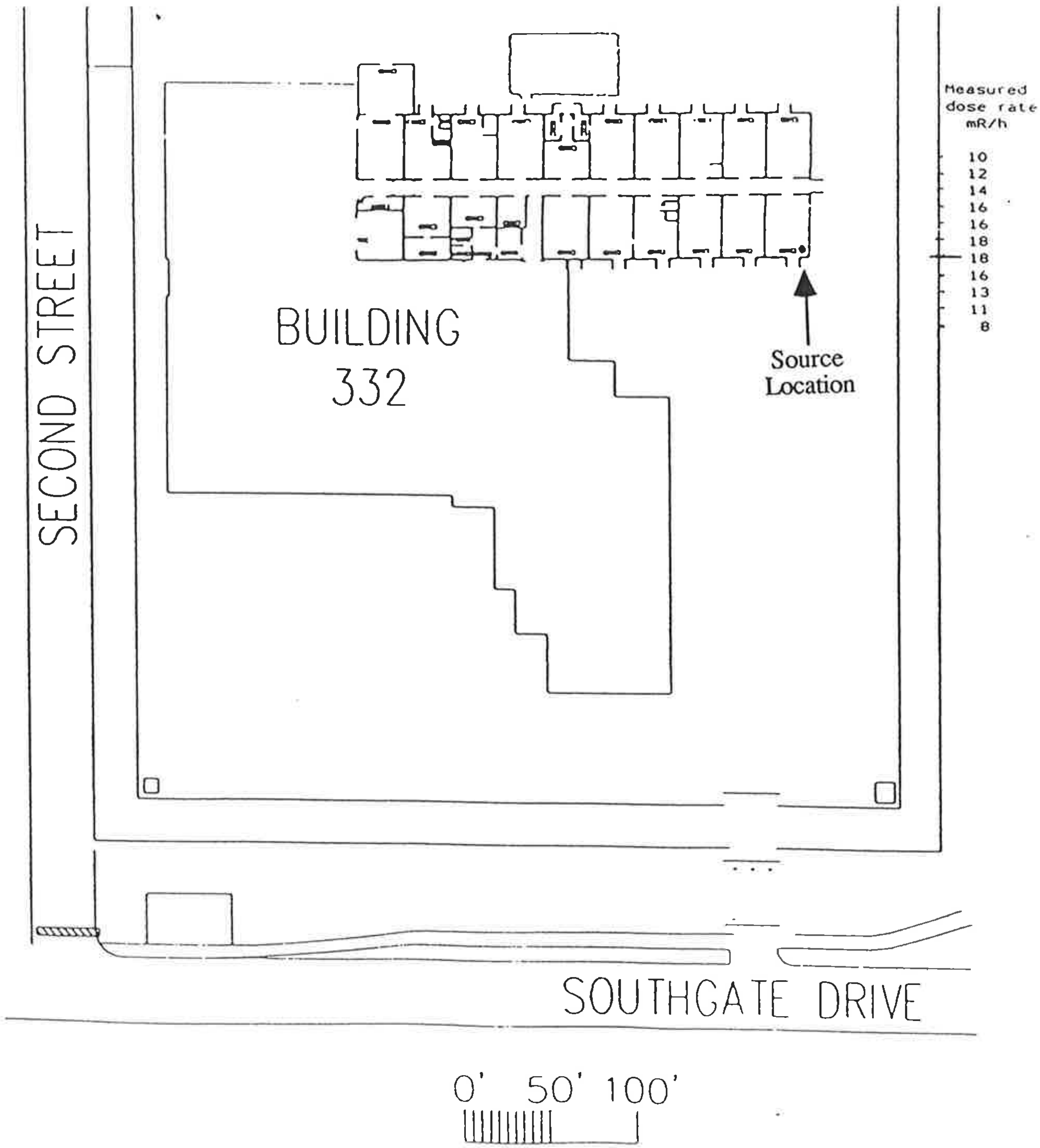
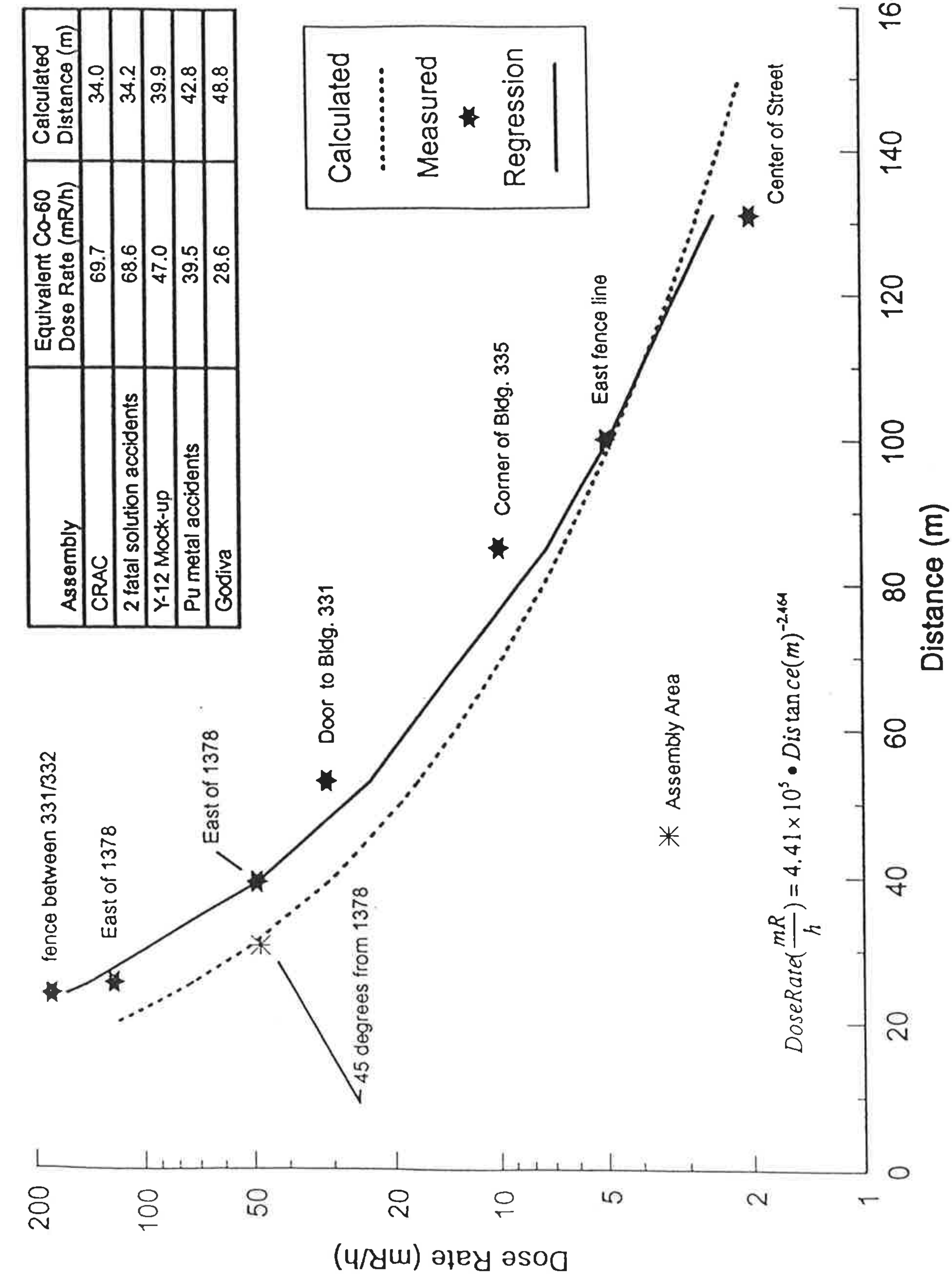


Figure 6. Measured dose rates outside Bldg 332 plotted as a function of distance from the building. Also shown is a curve showing the dose rates calculated using the inverse square relationship and applying an air absorption factor of 1/3. In the table at the right side of this figure is the equivalent Co-60 source dose rates for each of the assemblies or accidents discussed in the ANSI standard and the corresponding distance to the 12 rad line.



Assembly	Equivalent Co-60 Dose Rate (mR/h)	Calculated Distance (m)
CRAC	69.7	34.0
2 fatal solution accidents	68.6	34.2
Y-12 Mock-up	47.0	39.9
Pu metal accidents	39.5	42.8
Godiva	28.6	48.8

Figure 7. Sketch showing the 12 rad line around Bldg 332 using the assumption that the results from the CRAC critical assembly and the dose from 2 fatal solution accidents are applicable to Bldg 332. This 12 rad line should be used for Bldg 332.